NITROGEN FERTILIZER MANAGEMENT FOR MAXIMUM ECONOMIC YIELDS OF SPRING WHEAT IN SOUTHWESTERN SASKATCHEWAN

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ABSTRACT

The effects of snow trapping by means of alternative cereal stubble heights, and of N fertilizer management in terms of rates, times of application, and methods of placement on soil moisture conservation, grain yields, and economic returns for zero tilled continuous spring wheat were examined over a 6-yr period on a loam soil at Swift Current, Saskatchewan. The trap strips consisted of a portion of stubble 40-60 cm tall by 30 cm wide spaced every width of the swather (6 m) and perpendicular to the prevailing winds. Short stubble was cut at a uniform standard height of 15-20 cm. The water equivalent of snow trapped over the fall and winter periods averaged 85 mm in tall stubble and 45 mm in short stubble treatments; however, water conserved averaged only 11 mm higher in tall than in short stubble, and ranged from 6 mm lower to 27 mm higher. Efficiency of meltwater intake averaged 45% (range 13-66%) for tall stubble and 33% (range 22-43%) for short stubble. The low soil moisture conserved and low efficiency of meltwater intake in some years was due to high runoff losses caused by rapid melting of the snowpack in late winter by Chinook winds. The effect of stubble height and fertilizer management treatments on grain yields and economic returns varied with the level of growing season rainfall. In dry years, wheat yields on tall stubble areas averaged 166 $kg.ha^{-1}$ higher (655 vs 489 $kg.ha^{-1}$) than on short stubble areas, in moist years the yield advantage on tall stubble was 35 $kg.ha^{-1}$ (1566 vs 1531 $kg.ha^{-1}$), while in wet years the yield advantage of tall stubble was 68 $kg.ha^{-1}$ (2493 vs 2425 $kg.ha^{-1}$). Wheat yields were increased with N fertilizer in years with favorable moisture reaching a maximum at 75-100 $kg.ha^{-1}$. Furthermore, in years of favorable moisture, yields were generally greater for spring applied than for fall applied urea N, and for deep banded than for broadcast N. In contrast, in dry years wheat yields did not respond to N fertilizer or to the method of fertilizer management used. The overall relative yield ratings for spring band, fall band, spring broadcast and fall broadcast were 100, 98, 94, and 91, respectively. In dry years, net returns averaged 15-25 $\$.ha^{-1}$ higher on tall than short stubble; but, only 4-8 $\$.ha^{-1}$ higher in moist years and no difference in wet years. The economic benefit of snow trapping increased with the price for wheat and decreased with the cost for N fertilizer. In the dry years, fall broadcasting of N fertilizer provided the greatest profit due largely to the lower costs for fertilizer N and labor in the fall compared to spring period and to the lower energy and equipment ownership costs for broadcasting compared to banding fertilizer. In years with favorable moisture, there was generally little difference in net returns among the fertilizer management systems.

INTRODUCTION

Successful crop production in the Brown soil zone of Saskatchewan and Alberta requires adapting to low and variable amounts of water. Potential evapotranspiration normally exceeds growing season rainfall, thus a severe water shortage for plants develops unless an ample reserve of soil water is stored before planting (Nicholaichuk 1984). The source of this water reserve is the precipitation received during the non-growing period.

Traditionally summerfallowing has been the practice used by producers in this area to conserve soil water. Research has shown that conventional methods of summerfallowing conserve 15-25% of the precipitation that is received over the 21 month fallow period (Staple and Lehane 1952; Campbell et al. 1987). The remaining 75-85% of the precipitation is lost through evaporation, surface runoff, percolation below the rooting zone, and sublimation and blowoff of the snow pack.

The challenge for researchers is to develop new production systems that will improve soil moisture conservation, enhance efficient utilization of the available water, ensure better protection for the soil, and provide producers with equivalent or higher economic returns than that provided by the traditional fallow-wheat system. This paper reports on 6 years of results from an ongoing study to determine the influence of alternative snow and fertilizer management systems on winter precipitation conserved, grain yields, and on economic returns for spring wheat grown continuously on a zero tilled loam soil at Swift Current, Saskatchewan.

MATERIALS AND METHODS

The experiment, which was initiated at the Swift Current Research Station in 1982 on a Swinton silty loam soil (Ayres et al. 1985), has been described in detail by Campbell et al. (1986) and has been reported on at several previous Soils & Crops Workshops; thus, only a brief review is presented here.

The study consisted of two main stubble height treatments: a uniform short stubble and a tall-short stubble (hereafter called tall stubble). The short stubble plots were cut uniformly at the standard height of 15-20 cm. The tall stubble plots were created with a deflector attachment mounted on a self-propelled swather (Dyck et al. 1982). Each stubble height treatment was divided into three year-subplots which allowed the experiment to be moved yearly so as to minimize residual effects of fertilizer. The test-year subplots were divided into four N fertilizer (urea) sub-subplots. In first year the N fertilizer rates were 25, 50, 100, and 150 $kg.ha^{-1}$. In subsequent years the 150 $kg.ha^{-1}$ rate was changed to 75 $kg.ha^{-1}$. Each N fertilizer rate treatment was divided into two sub-sub-subplots which compared broadcast application to deep banding. There was a further split which allowed comparison of fall versus spring application of N. The year-plots not under test (hereafter called filler plots) received 25 $kg.ha^{-1}$ N and P_2O_5 fertilizer applied with the seed.

Each replicate was staked in the fall to facilitate soil and snow sampling at the same points each time of measurement. Soil cores were taken in fall (usually late September) and spring (usually early May) close to each stake for soil moisture, NO_3-N, and $NaHCO_3$-P determinations by soil depth. Snow surveys were taken whenever there was a significant change in the snow pack.

Growing season rainfall, air temperatures, and wind speeds were recorded at a meteorological station located 0.5 km to the east of the test site.

The economic optimum rates of N fertilizer and the associated net returns for each method and time of N placement were calculated for a range of wheat prices and fertilizer costs. Multiple regression was used to relate yields for each fertilizer management treatment to total available N at time of planting (i.e., soil test NO_3-N in 0-60 cm depth plus applied N fertilizer). For this purpose, the data were arbitrarily separated into dry years (1984 and 1985), normal years (1983 and 1987), and wet years (1982 and 1986) and second degree polynomial relationships (regressed through the origin) were determined. The first derivative of the relationships were solved for rates of total available N that maximized physical yields and for rates of total available N that maximized net returns at various fertilizer N cost/wheat price ratios. Net return was defined as income above the cost of the fertilizer and fertilizer application. A risk allowance factor of 1.5 (i.e., the last dollar spent of fertilizer N provides 1.5 dollars of return) as defined by the Saskatchewan Soil Testing Laboratory was assumed. In the analysis, emphasis was placed on the assumed higher cost of N fertilizer and farm labor in the spring compared to fall, the higher costs for energy and equipment ownership for banding compared to broadcasting fertilizer, and the interest charges on operating capital (Table 1).

Table 1. Summary of Economic Assumptions

Item	Cost	Units
Farm Labor - Fall	6.00	$\$.hr^{-1}$
- Spring	12.00	$\$.hr^{-1}$
Fertilizer N Cost - Fall	0.85	index
- Spring	1.00	index
Banding - variable plus fixed cost	14.62	$\$.ha^{-1}$
- labor required	0.201	$hr.ha^{-1}$
Broadcasting - variable plus fixed cost	3.60	$\$.ha^{-1}$
- labor required	0.124	$hr.ha^{-1}$
Interest Rate	10.	%

RESULTS AND DISCUSSION

Precipitation and Weather Conditions

The weather during the 6 years of study reinforced the historical pattern of extreme variability (Table 2). Precipitation received between fall and spring soil sampling averaged 94 mm and ranged from 63 mm in 1985-86 to 132 mm in 1981-82. Growing season (May-July) rainfall was less than 60% of the long-term average in 1984 and 1985, near average in 1983 and 1987, and more than 20% above the long-term average in 1982 and 1986. Growing season air temperatures and wind speeds in these dry years were also above average resulting in severe moisture stress for growing plants (data not shown).

Snow and Soil Moisture Conservation

Each year, significantly more snow was trapped in tall (avg depth of 33 cm) than in short (avg depth of 19 cm) stubble treatments (Table 3). Further, the snow trapped was observed to persist in the tall stubble areas for days after it had disappeared from short stubble areas during periods of warm Chinook winds. The water equivalent of snow trapped during the first 5 years averaged 85 mm or 88% of the fall to spring precipitation received in tall stubble treatments, and 45 mm or 46% of the fall to spring precipitation received in short stubble treatments. It was greater than the precipitation received during the fall to spring period for the tall stubble treatments in 1983-84 and 1985-86. In contrast, the water equivalent of snow trapped on short stubble areas was below the level of fall to spring precipitation received in all years, reflecting the greater snow loss through blowoff. One problem foreseen for this snow trapping technique in the Brown soil zone is that in dry years restricted soil water supply when stubble cropping will result in insufficient stubble height for construction of adequate snow trap strips.

Table 2. Precipitation Received at Swift Current (1981-87)

Crop-Year	Fall to Spring[+]	May	June	July	Growing Season
	------------------	------	(mm)	------	------------------
1981-82	132	82	43	119	244
1982-83	93	62	29	96	187
1983-84	68	19	67	15	101
1984-85	131	31	17	25	73
1985-86	63	122	51	32	205
1986-87	75	26	44	59	129
Mean	94	57	42	58	157
LT Avg. (99 yr)	120[‡]	43	71	52	166

[+] Precipitation received between late fall and early spring soil sampling.
[‡] Refers to precipitation received between October 1 and April 30.

The extra water conserved in tall stubble compared to short stubble areas averaged 11 mm in the top 120 cm of soil and varied from a low of -6 mm in 1985-86 to a high of 27 mm in 1984-85 (Table 3). These results are similar to those reported by Nicholaichuk (1980) and Kachanoski (1985), but are substantially below the extra 45 mm of available soil moisture by which fallow fields exceed stubble fields on average in the Brown soil zone (de Jong and Steppuhn 1983; Campbell et al. 1987). The efficiency of meltwater intake averaged 45% for tall stubble and 33% for short stubble. The efficiency of meltwater intake for short stubble is similar to that reported for this system in the past (Campbell et al. 1987). The high efficiency of meltwater intake in tall stubble plots in 1983-84, 1984-85, and 1986-87 was due to a combination of factors

Table 3. Conservation and Efficiency of Intake of Fall and Winter Precipitation by Stubble Treatments

Season	Precip. Fall to Spring	Stubble Height Tall	Stubble Height Short	Mean Snow Depth Tall	Mean Snow Depth Short	Water in Snow Tall	Water in Snow Short	Available water in soil+ Fall Tall	Available water in soil+ Fall Short	Available water in soil+ Spring Tall	Available water in soil+ Spring Short	Water Conserved Tall	Water Conserved Short	Advtg. of Tall Stubble	% Efficiency of intake of precip. Tall	% Efficiency of intake of precip. Short.
	(mm)	(cm)		(cm)		(mm)		(mm 120 cm^{-1})				(mm 120 cm^{-1})		(mm 120 cm^{-1})		
1981-82	132	60	20	39	17	97	43	-10	-10	38	28	47	38	9	35	29
1982-83	93	52	19	20	17	40	34	80	67	111	93	31	26	5	33	28
1983-84	68	45	15	25	12	69	27	14	22	58	42	45	20	25	66	29
1984-85	131	40	14	41	24	122	61	-1	0	82	56	83	56	27	63	43
1985-86	63	39	13	38	24	100	60	30	16	39	33	8	14	-6	13	22
1986-87	75	ND	ND	ND	ND	ND	ND	41	45	83	80	42	34	8	57	46
Mean	94	47	16	33	19	85	45	23	19	68	55	43	31	11	45	33
Sx- (Stub Ht)		1.0		1.0		2		--		3		3		--	5	
Sx- (Yr)		1.7		1.4		3		4		6		7		8	7	
Sx- (Ht x Yr)		2.2		1.5		4		--		--		9		--	9	
Significant Factors																
Stubble height (Ht)		**		**		**		NS		**		**		--	**	
Year (Yr)		**		**		**		**		**		**		*	**	
Ht x Yr		**		**		**		NS		NS		*		--	*	

+ Available water = water held by soil at potentials about -4MPa; at -4MPa this soil retains 154 mm of water in 120 cm depth.
*, ** Significant at P<0.05 and at P<0.01, respectively; NS, not significant.

including the relatively dry soil conditions in the fall, few Chinook winds during winter which minimized the formation of ice layers at or near the soil surface, and a slow spring melting of the snowpack. In contrast, the particularly low efficiency of meltwater intake in 1985-86 was due to thawing and refreezing of meltwater in the warmer than usual winter which formed ice layers that sealed the soil surface, and a rapid thaw and runoff in late winter as a result of a Chinook. Significant runoff losses of meltwater also occurred in the first two years of the study as a result of rapid spring melting of the snowpack, despite dry soil conditions in the fall of 1981 and wet soil conditions in the fall of 1982. These results highlight a second problem with snow trapping: that of obtaining good infiltration of meltwater during periods of rapid thaw by Chinook winds, especially when soil moisture is high going into the winter period (de Jong and Steppuhn 1983).

Effect of Stubble Height and N Fertilizer on Grain Yields

Spring wheat yields were directly related (r=0.90) to the level of growing season rainfall received (Table 4). In years of favorable moisture, yields were increased by application of N fertilizer; maximum yields in these years were obtained at N fertilizer rates of 75-100 $kg.ha^{-1}$ (Table 4). At these rates of N fertilizer, yields were often 70-100% higher than those obtained on the filler plot areas which received only minimal N fertilizer. In dry years, crop yields did not respond to N fertilizer, and test plot yields were generally lower than those obtained on filler plots. This latter effect occurred because the higher rates of N fertilizer stimulated rapid and lush early growth of the wheat plants which utilized all of the available soil water and the plants became completely desiccated before the scant summer rains came. In contrast, plants receiving lower rates of N fertilizer grew more slowly and utilized less water and were able to use summer rains more efficiently. This problem of little yield response or of depressing crop yields by application of moderately high rates of N fertilizer is not uncommon with stubble cropping in the Brown soil zone, and since drought can be expected as a rule rather than the exception, care must be taken not to over-fertilize.

In 4 of 6 years, yields were higher ($P<0.05$) on tall stubble than on short stubble (Table 4). The overall yield advantage of tall stubble averaged 93 $kg.ha^{-1}$ or about 6% more, and was particularly significant in years of low growing season rainfall. However, the extra moisture conserved by tall stubble cannot account for the yield difference between stubble heights in some years (e.g., 1984). We believe that the zero till-trap strip combination may also be increasing yield by reducing evapotranspiration through reduced winds speeds near the soil surface. In 1982 a significant ($P<0.05$) interaction between N rate and stubble height on grain yield was observed; at low N rates tall stubble yielded more than short stubble, while at high N rates the converse was true. This was explained in terms of differences in rates of soil water use and the timing of growing season rainfall (Campbell et al. 1986).

The effect of timing and method of N application on grain yields varied with the year (Table 5). During the dry years there was no effect of either method of N placement nor time of N application on yield. In contrast, in the wettest year (1982), spring banded N gave the highest yields, fall banded and spring broadcast N were similar and ranked second highest, and fall broadcast gave the lowest yields. The yield difference between spring banded and fall broadcast treatments in this year averaged 325 $kg.ha^{-1}$ or 15% higher. In 1983,

Table 4. Soil N and Effect of Stubble Height and N Fertilizer on Wheat Yields§

Year	Soil NO_3-N (0-60 cm)	Stubble Height	Fertilizer N Rate ($kg.ha^{-1}$)+ 25	50	75	100	Mean	Filler Plots
	($kg.ha^{-1}$)		($kg.ha^{-1}$)					
1982	26	Tall	2008	2226	(2350)‡	2484	2267	1418
		Short	1813	2070	(2406)‡	2662	2238	1131
		Mean	1911	2148	(2378)‡	2573	2253	1275
1983	13	Tall	1396	1635	1968	1988	1747	1107
		Short	1358	1627	1651	1900	1634	1181
		Mean	1377	1631	1809	1944	1690	1144
1984	14	Tall	653	585	710	723	645	864
		Short	489	456	436	476	464	629
		Mean	571	521	573	600	566	747
1985	25	Tall	784	683	546	645	665	1000
		Short	554	514	523	462	513	749
		Mean	669	599	534	553	589	875
1986	49	Tall	2638	2609	2834	2790	2718	ND
		Short	2529	2625	2606	2689	2612	ND
		Mean	2583	2617	2720	2740	2665	ND
1987	23	Tall	1165	1328	1456	1588	1384	ND
		Short	1288	1387	1503	1535	1428	ND
		Mean	1227	1358	1480	1562	1406	ND
1982-87	25	Tall	1441	1511	1644	1703	1575	1097
		Short	1339	1446	1521	1621	1482	923
		Mean	1390	1479	1583	1662	1529	1010

§ Values are averaged over time and method of N application.
\+ Main effects for the test plots (year, stubble height and N fertilizer) were significant ($P<0.05$) as were several interactions.
‡ Estimates based on missing plot techniques.

a year with more average rainfall, all fertilizer management systems except fall broadcast N gave similar yields; fall broadcast N gave 126-158 $kg.ha^{-1}$ less yield than the other treatments. In 1986 and 1987, there was no effect of time of N application, but yields averaged 81 and 238 $kg.ha^{-1}$ higher in the respective years for banded compared to broadcast N. When averaged over the years, the overall relative responses to the N management systems were rated 100, 98, 94, and 91 for spring band, fall band, spring broadcast, and fall broadcast, respectively. This compares to rating of 100, 100, 83, and 75 reported for the same fertilizer management systems in the dry regions of Alberta (Penny 1985).

Table 5. Effect of Time and Method of N Placement on Yield of Wheat[+]

Year	Method of N Placement	Time of N Application[‡] Fall	Spring	Mean
		($kg.ha^{-1}$)		
1982	Band	2286	2389	2338
	Broadcast	2039	2296	2168
	Mean	2163	2343	2253
1983	Band	1657	1729	1693
	Broadcast	1474	1660	1567
	Mean	1566	1645	1631
1984	Band	559	559	559
	Broadcast	563	552	558
	Mean	561	556	559
1985	Band	592	596	594
	Broadcast	603	575	589
	Mean	598	586	592
1986	Band	2712	2673	2693
	Broadcast	2649	2574	2612
	Mean	2681	2624	2653
1987	Band	1506	1544	1525
	Broadcast	1267	1307	1287
	Mean	1387	1426	1406
1982-87[§]	Band	1552	1582	1567
	Broadcast	1433	1494	1464
	Mean	1493	1538	1516

[+] Values are averaged across stubble height and rates of fertilizer.
[‡] In 1985 these treaments were early-April and mid-May because early arrival of winter prevented a fall application.
[§] All main effects and several of the second and third order interactions were highly significant.

Relationship of Yields to Total Available N and Optimal Levels of Available N

Regression analysis showed that yields responded in a curvilinear fashion to increasing levels of total available N at time of planting (Table 6). The economic optimum levels of available N were lower than those which maximized grain yields; they increased with the level of available water, and decreased as the ratio of N fertilizer cost to wheat price increased (Table 7). In dry years the optimum levels of available N averaged about 5 to 15 $kg.ha^{-1}$ higher on tall than on short stubble because of the greater available soil moisture, and were similar regardless of time or method of N application used. In years with average moisture, the optimum levels of available N for wheat grown on tall stubble plots averaged 10 to 15 $kg.ha^{-1}$ higher when the N was applied in fall compared to spring; this effect was not evident for wheat grown on short

Table 6. Regression Coefficients for Second Order Polynomial of Yield and Total Available N (TN) by Fertilizer Management System[+]

Stubble Height/Time/Method	Regression Coefficients[‡]		
	TN	TN^2	R^2
Dry Years			
Tall - Fall & Spring - Band & Broadcast	17.53	-0.104	90
Short - Fall & Spring - Band & Broadcast	13.12	-0.079	86
Normal Years			
Tall - Fall - Band	34.37	-0.155	97
- Broadcast	30.19	-0.141	96
- Spring - Band	40.30	-0.217	97
- Broadcast	37.75	-0.208	94
Short - Fall - Band	36.37	-0.191	98
- Broadcast	32.12	-0.165	96
- Spring - Band	38.76	-0.201	98
- Broadcast	37.11	-0.205	97
Wet Years			
Short & Tall - Fall & Spring - Band	45.95	-0.191	98
Short & Tall - Fall & Spring - Broadcast	41.90	-0.165	97

[+] Total available N refers to soil NO_3-N in 0 to 60 cm depth plus applied N fertilizer.
[‡] All regression coefficients are significant at $P < 0.05$ or higher.

Table 7. Economic Optimum Levels of Total Available N

Stubble Height/Time/Method	Maximum Yield[+]	Fertilizer N Cost/Wheat Price[‡]				
		2	3	4	5	6
		(kg/ha)				
Dry Years						
Tall - Fall & Spring - Band & Broadcast	85	70	63	56	48	41
Short - Fall & Spring - Band & Broadcast	83	64	55	45	36	26
Normal Years						
Tall - Fall - Band	111	101	96	91	87	82
- Broadcast	107	96	91	86	80	75
- Spring - Band	93	86	82	79	75	72
- Broadcast	91	84	80	76	73	69
Short - Fall - Band	95	87	84	80	76	72
- Broadcast	97	88	84	79	75	70
- Spring - Band	97	89	85	82	78	74
- Broadcast	91	83	80	76	72	69
Wet Years						
Tall & Short - Fall & Spring - Band	120	112	109	105	101	97
Tall & Short - Fall & Spring - Broadcast	127	118	113	109	104	100

[+] Level of total available N that maximizes yield.
[‡] Values include a risk factor, i.e., the last $1.00 expenditure on fertilizer N returns $1.50 of additional yield.

stubble. In wet years, the optimum available N levels were higher when the N fertilizer was broadcast compared to banded; no other factors were significant.

Effects of Fertilizer Management System on Net Returns

Net returns (i.e., revenue above the cost of fertilizer and fertilizer application) averaged 15-25 $\$.ha^{-1}$ higher on tall stubble than on short stubble in dry years, but only 4-8 $\$.ha^{-1}$ higher in years with average moisture, and no difference in wet years (Table 8). In dry years, broadcasting N fertilizer was more profitable than banding it. Further, fall application of fertilizer N was generally more profitable than spring application because of the assumed lower fertilizer and labor costs in the fall period. In contrast, in years with average moisture, fall broadcasting provided the lowest net return; there was little difference in net returns among the other fertilizer management systems. In wet years, banding provided similar net returns as broadcasting, with fall application slightly more profitable than spring application.

CONCLUSIONS

1. By using cereal trap strips instead of stubble cut at a uniform standard height of 15 to 20 cm, we have only been able to conserve 11 mm of extra water, instead of the 45 mm that we had hoped for (i.e., the average difference between fallow and stubble fields in the Brown soil zone). The major problem is to get the meltwater to infiltrate into the soil when the snowpack is melted by Chinook winds during winter and by rapid spring thaws. It appears, however, that the conserved water is being used more efficiently than that stored in fallow.

2. Yield analysis shows clearly that broadcasting N in the fall is the worst scenario of the band-broadcast-spring-fall application combinations. The 6-yr average rankings in yields are 100, 98, 94, and 91 for spring band, fall band, spring broadcast, and fall broadcast, respectively.

3. But, the economics suggests that fall broadcasting may well be the best scenario. In dry years, broadcast application was more profitable than banding, while in years with favorable moisture there was often little difference in net returns among the various fertilizer management systems. The increased revenue from the sale of higher yields from the best fertilizer management systems were often offset by the higher costs for fertilizer N in the spring compared to fall, or by the higher costs for energy and labor for band compared to broadcast application. The economic picture for banding fertilizer would improve if it could be combined with another field operation or if zero till seeding equipment capable of banding fertilizer separate from the seed were to become readily available.

4. Net returns averaged 15-25 $\$.ha^{-1}$ higher on trap strip plots than on standard stubble plots in dry years, but the advantage was only 4-8 $\$.ha^{-1}$ in moist years, and no difference in wet years.

5. Although not shown in this paper, the combination of zero tillage-continuous cropping with adequate fertilization has improved the quality of the soil significantly in the short span of 6 years. Further, water

Table 8. Effect of Changes in Wheat Prices and Fertilizer Costs on Net Returns[+]

	Wheat Price = $90/t			Wheat Price = $110/t			Wheat Price = $130/t		
	N Fertilizer Cost ($/kg)‡			N Fertilizer Cost ($/kg)‡			N Fertilizer Cost ($/kg)‡		
Stubble Height/Time/Method	0.33	0.44	0.55	0.33	0.44	0.55	0.33	0.44	0.55
	($/ha)								
Dry Years									
Tall - Fall - Band	25	17	10	39	32	24	54	46	39
- Broadcast	37	30	23	52	44	37	67	59	51
- Spring - Band	22	15	8	37	29	21	51	43	35
- Broadcast	35	27	20	49	41	33	64	55	47
Short - Fall - Band	8	1	-5	19	12	5	29	22	15
- Broadcast	21	14	7	31	24	17	42	35	27
- Spring - Band	6	-1	-7	16	9	2	27	19	12
- Broadcast	19	12	5	29	22	15	39	32	24
Normal Years									
Tall - Fall - Band	121	110	100	159	148	137	197	186	175
- Broadcast	109	98	89	141	130	120	173	162	152
- Spring - Band	120	110	101	157	147	137	194	184	174
- Broadcast	119	110	100	153	143	134	187	177	168
Short - Fall - Band	110	101	92	145	135	126	179	170	161
- Broadcast	107	98	89	138	128	119	169	159	150
- Spring - Band	119	109	99	156	146	136	193	183	173
- Broadcast	116	107	98	150	140	131	183	173	164
Wet Years									
Tall - Fall - Band	195	183	172	250	238	227	305	294	282
& - Broadcast	196	184	172	249	237	225	302	290	278
Short - Spring - Band	191	178	166	246	233	221	301	288	275
- Broadcast	192	179	165	245	231	218	298	284	270

[+] Income above costs of fertilizer and fertilizer application.

‡ N fertilizer cost in spring; fall fertilizer costs are 85% of spring.

infiltration appears to have also improved with time. But, possibly the greatest drawback to this system so far has been the increase in grassy weeds with time.

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